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955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

date: October 26, 1971

to: Distribution

from: R. J. Stern

subject: Shaping the LOI Orbit to Satisfy DOI Bailout Requirements for Far Easterly Sites -- Case 310

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ABSTRACT

LOI trajectory "shaping" is considered as a means of increasing the communication and tracking time between DOI and perilune for a far easterly landing site such as in the region southwest of Crisium. For a mission to a typical site (15.7°N, 46.4°E) using the current 60 x 170 nm LOI orbit, the spacecraft is visible to the earth during DOI (on the western limb of the moon) and for approximately four minutes before LOS. The time available after AOS (on the eastern limb) and before perilune is limited to about five minutes.

Additional coverage time before LOS can be achieved by employing a lower perilune on the LOI orbit at the expense of additional SPS ΔV. For example, using a 50 x 170 nm LOI orbit, 15 minutes of coverage between DOI and LOS can be achieved at the expense of an additional 110 ft/sec in end-of-mission SPS ΔV.

The four minutes of coverage before LOS on the 60 x 170 nm orbit may possibly be used to reduce the time required after AOS to perform the bailout maneuver. If this is not possible, then additional trajectory modification would be required. However, if SPS propellant margins are low on a Crisium mission, any method of dealing with the DOI bailout problem that costs ΔV will not appear attractive and other methods such as a two-step DOI might be more advantageous. This method would use the SPS to bring perilune down to an intermediate altitude such as 100,000 ft in the first step and then the RCS would complete the maneuver on the next revolution. The low thrust level of the RCS makes a few seconds of overburn non-critical.

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MEMORANDUM FOR FILE

Introduction

Current planning for Apollo missions calls for LOI into a 60 x 170 nm orbit followed by a DOI maneuver on the 2nd revolution into a 60 x 8 nm orbit from which LM descent will begin approximately a day later. For far easterly sites such as SW Crisium, concern has been expressed as to the amount of time available after acquisition of signal (AOS) to perform a DOI bailout maneuver in the event of a DOI overburn resulting in an orbit with an unacceptably low perilune.

In the event of a DOI overburn ten minutes are normally required after AOS to determine an unsafe perilune altitude situation and command the bailout maneuver. This time breaks down roughly to 4 minutes tracking, 2 minutes processing of data, 1 minute to examine the data and 3 minutes to instruct the crew. Since the time of visibility from AOS (on the eastern limb) to an unsafe altitude will generally be less than five minutes for a far easterly site such as Crisium, an alternate scheme would be necessary. Several methods have been proposed to alleviate this problem. These include locating perilune of the descent orbit over the landing site instead of 16-17° eastward (adopted on Apollo 15), employing the RCS for the final maneuver of a two-step DOI, and LOI orbit shaping which employs initial lunar orbits with perilune altitudes as low as 40 nm.

Only the latter method is investigated here. It is shown that for a typical SW Crisium site (15.7°N, 46.4°E) the standard DOI maneuver from a 60 x 170 nm orbit is visible to the earth on the western limb of the moon and the spacecraft remains visible for several minutes. The time of visibility immediately after DOI and before occultation by the moon can be increased using a lower perilune altitude of the LOI orbit at the expense of an SPS ΔV penalty.

(NASA-CR-125920) SHAPING THE LOI ORBIT TO SATISFY DOI BAILOUT REQUIREMENTS FOR FAR EASTERLY SITES (Bellcomm, Inc.) 9 p

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Analysis

The orbital geometry for a representative 50 x 170 nm LOI orbit and 60 x 8 nm descent orbit is illustrated in Figure 1. Perilune of the descent orbit was placed 16° east of the landing site. When a 60 x 170 LOI orbit is employed the two orbits have only one spatial point in common and DOI must occur at this point, namely perilune of the LOI orbit (also the apolune of the descent orbit). If perilune of the LOI orbit is lowered, then the two orbits can interstect at two points and the DOI maneuver may take place at either point. These two maneuvers are classified here as pre or post perilune depending on their position with respect to perilune of the LOI orbit. Furthermore, the line of apsides of the LOI orbit can be rotated about the line of apsides of the descent orbit. This rotation can extend until the two orbits become tangent to each other and only one DOI solution exists. For a 50 x 170 orbit the rotation angle, θ, can extend to $\pm 61°$; for a 40 x 170 orbit the limiting values are $\pm 87°$. Beyond these limits the two orbits have no common intersection and a one-step DOI maneuver is not possible. For each orbit orientation the sun elevation at landing was fixed (7°). Therefore, the trans-lunar energy is approximately constant in the analysis.

Results

Figure 2 illustrates the penalty in combined LOI + DOI ΔV as a function of the rotation angle, θ, for LOI orbits of 40 x 170 nm and 50 x 170 nm. The combined ΔV penalty was essentially the same for either a pre- or post-perilune DOI maneuver. The effective penalty in end-of-mission ΔV is approximately twice the combined LOI + DOI penalty. Figure 3 illustrates the time from DOI to LOS on the western limb for the same orbital parameters as Figure 2. Pre- and post-perilune solutions are designated on the curves. It may be noted that for a limited range of rotation angle both DOI solutions are post perilune. Figure 4 is a crossplot of Figures 2 and 3. The time of visibility before occultation by the moon is illustrated as a function of the ΔV penalty (LOI + DOI) relative to the standard 60 x 170 case. The standard 60 x 170 orbit provides for about 4 minutes of visibility after DOI with respect to the earth. The visibility time can be increased on a 50 x 170 or 40 x 170 orbit at the expense of additional ΔV. For example, on a 50 x 170 orbit, Figure 4 reveals that a DOI solution yielding 15 minutes of earth coverage immediately after DOI is feasible at the cost of an additional 55 ft/sec in LOI + DOI ΔV.

Discussion

The fact that DOI is visible to earth (for the standard 60 x 170 nm LOI orbit) may provide the means for alleviating the DOI bailout problem for a Crisium mission. It appears possible to choose an LOI orbit of approximately 60 nm perilune altitude without incurring a significant ΔV penalty so that 4 minutes of coverage for tracking is available before LOS. The data can then be processed while the spacecraft is behind the moon and enough time may exist for the crew to be instructed upon AOS. Additional coverage time before LOS could be achieved only at the expense of additional ΔV. Alternate schemes may be desirable; such as a two-step DOI, if SPS margins on an Apollo 17 Crisium mission are low.

R. J. Stern

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Attachments

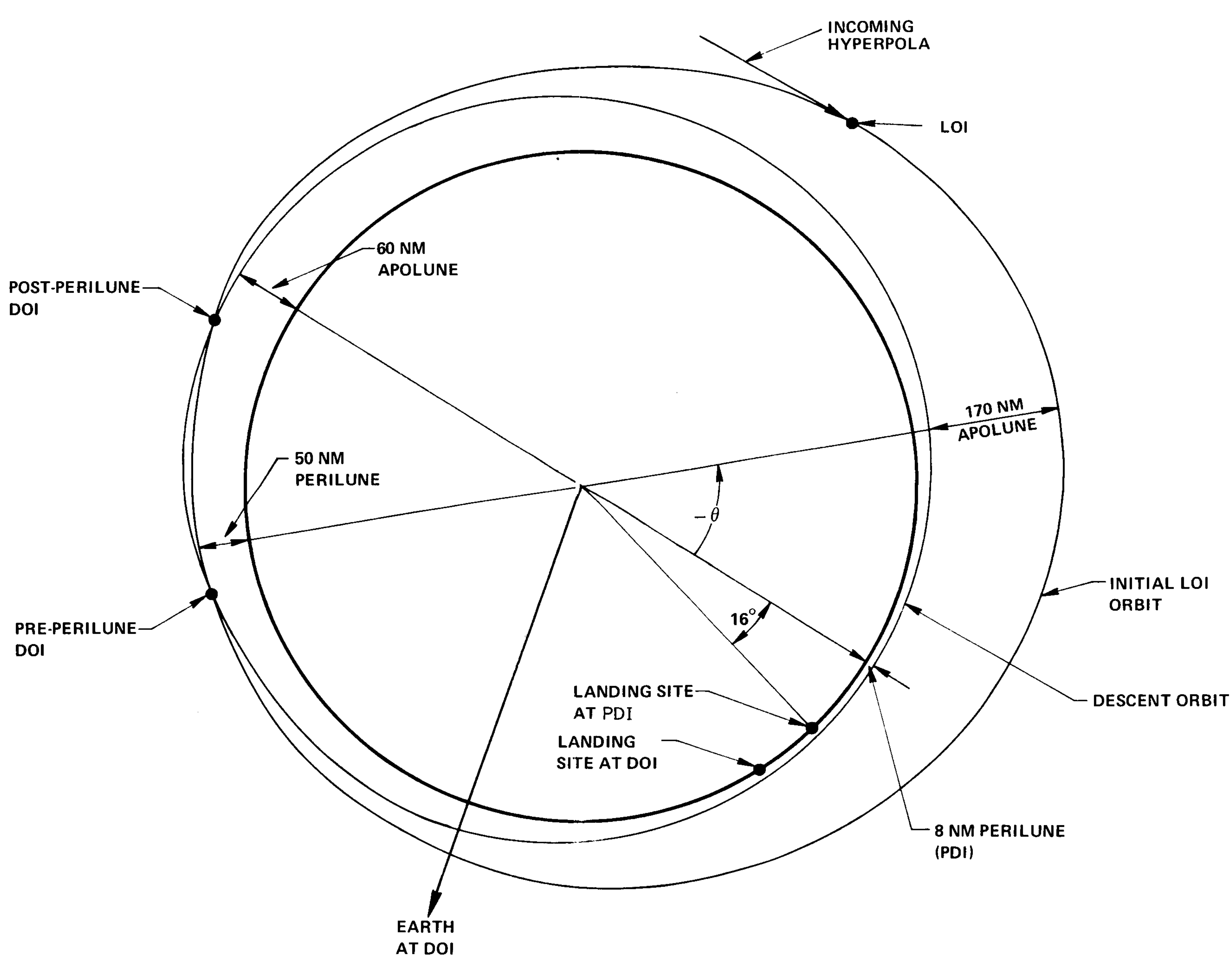

FIGURE 1 - ORBITAL GEOMETRY

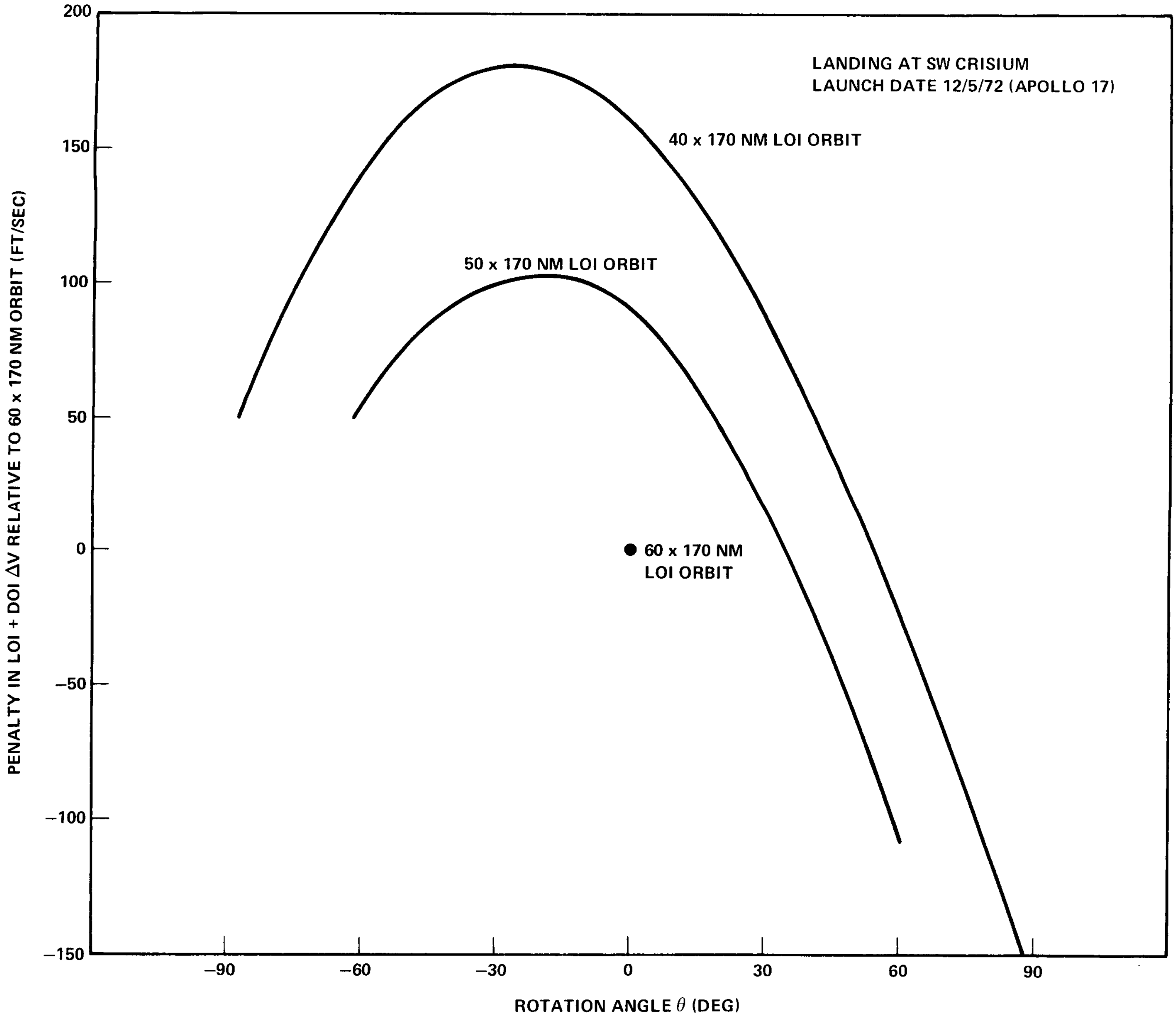

FIGURE 2 - LOI + DOI ΔV PENALTY

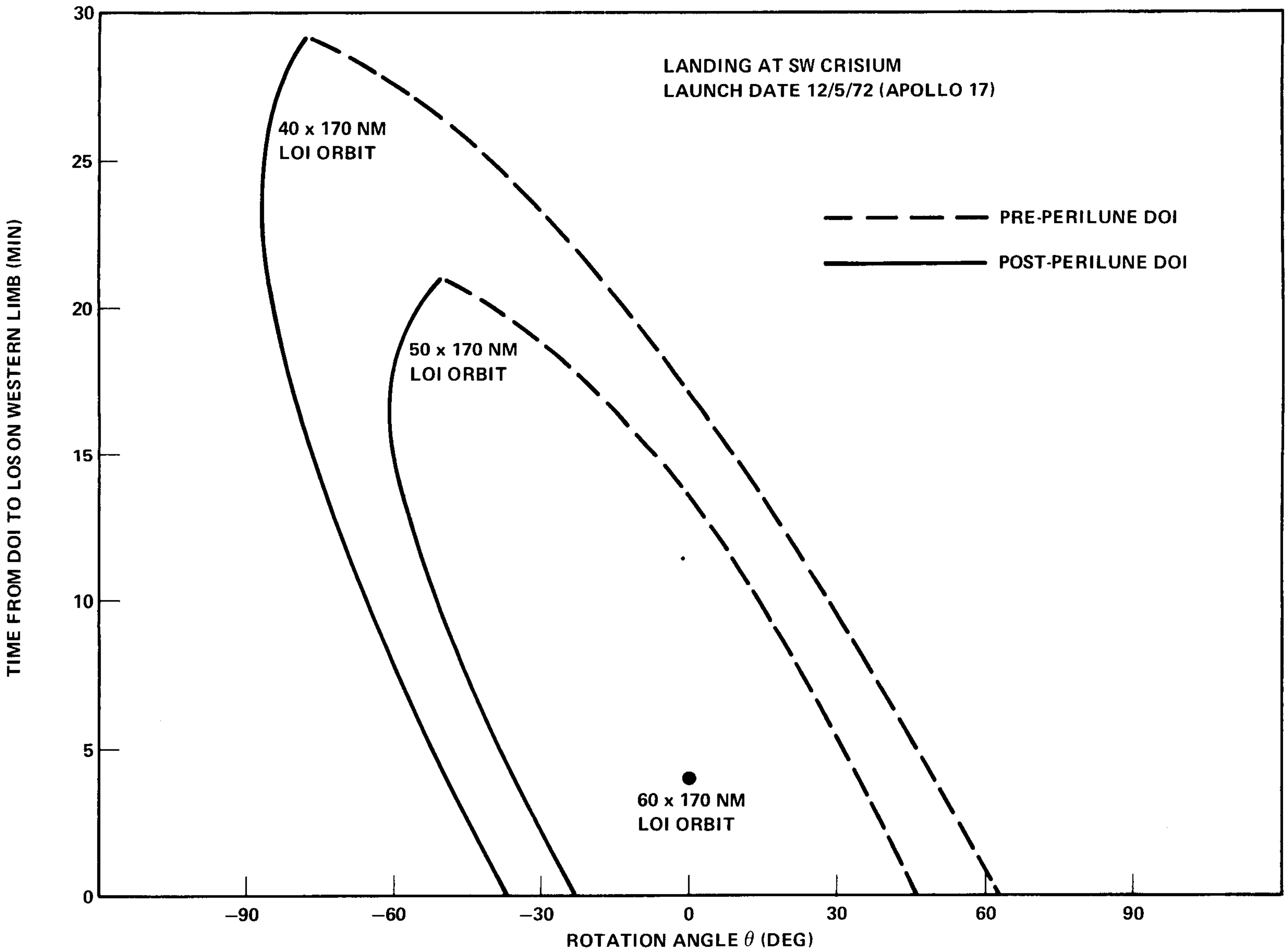

FIGURE 3 - VISIBILITY TIME AFTER DOI

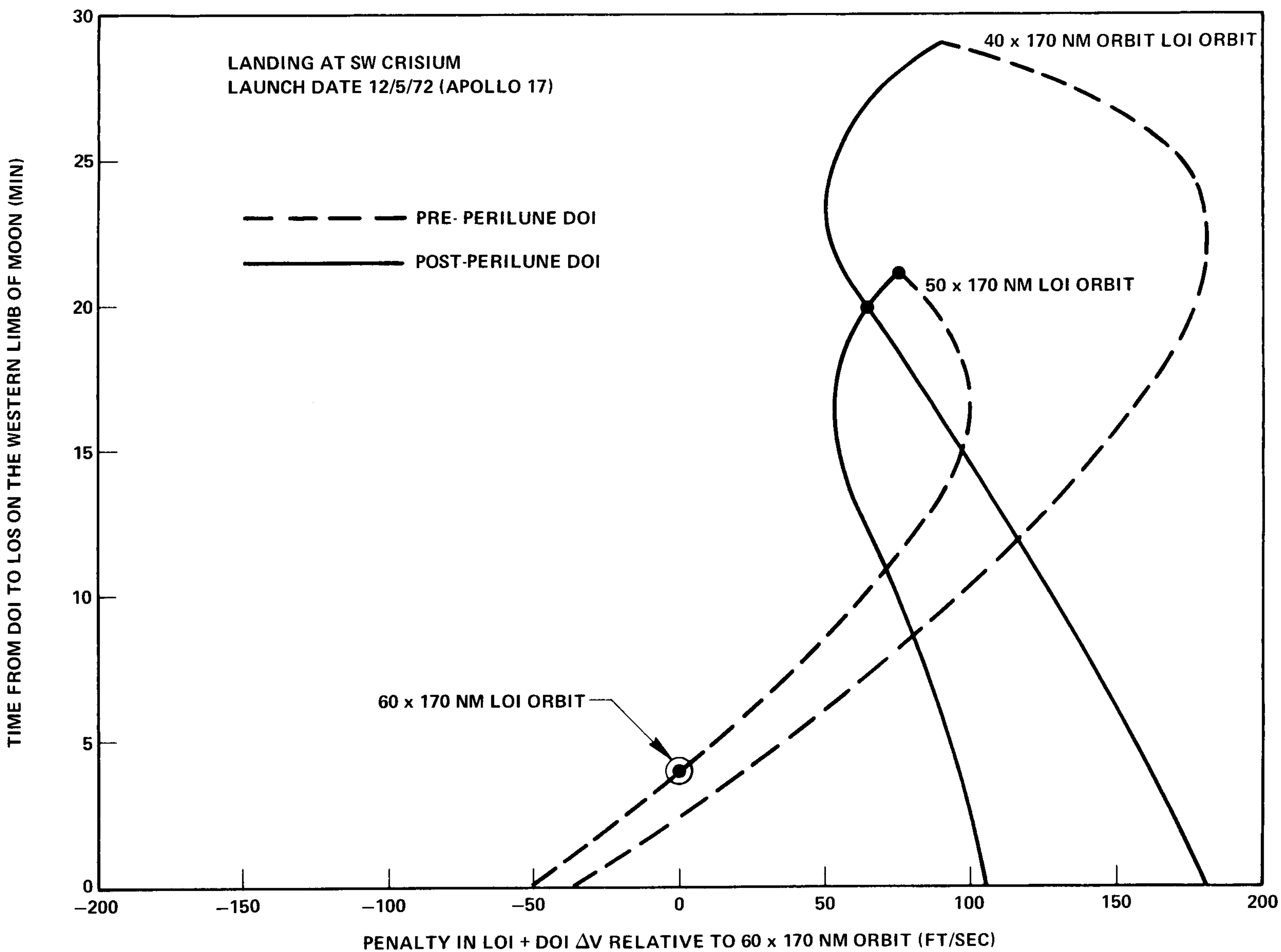

FIGURE 4 - VISIBILITY TIME VS LOI + DOI PENALTY

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